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THE "EOLE" PROGRAM

Centre National D'Etudes Spatiales

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FOREWORD

The EOLE program is an experiment in global meteorology based on the use of a satellite and a large number of automatic meteorological stations carried by balloons to a constant altitude in order to observe the general evolution of the troposphere.

The satellite, adapted for the two principal functions of localization and data collection, follows the movement of the balloons in the Southern Hemisphere, collects and relays the measurements made by the balloons to the ground.

Actually the EOLE experiment is not related solely to meteorology. The system which it uses is open to a large number of applications based on one or even on both functions of the satellite: localization and data collection.

It is in this spirit that agreement was reached to take advantage of the availability of EOLE after the gradual disappearance of the balloons to carry our various experiments of a scientific and technical nature in order to study the prospects offered by a system of localization and information collection.

Consequently this concerns exploratory experiments aimed at two objectives:

--To arouse the interest of potential users by showing them the possibilities of the EOLE system,

--To orient future systems which the CNES (National Space Study Center) may conceive, according to need.

THE "EOLE" PROGRAM

ABSTRACT: The EOLE Program is an experimental program to determine the effectiveness of satellite monitoring of drifting buoys and balloons in the Southern Hemisphere. This paper summarizes the results of the program thus far and considers the future need and demand for this type of service in determining the position of ships and in collecting and transmitting data of hydrological, oceanographic and meteorological interest.

I. Summary of Operations /1*

a. The Satellite

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Launched on 16 August 1971 by an American Scout rocket from the NASA base on Wallops Island, the EOLE satellite was placed in orbit, 903 km at apogee, 680 km at perigee, inclined 50° to the Equator with a period of 100 minutes.

(A11)

Stabilization of this satellite in its orbit was achieved on 19 and 20 August 1971. This delicate operation, tested with the PEOLE satellite, requires the remote controlled extension of a mast 10 m long.

Since then, EOLE has been in an ideal position to carry out the experiment, i.e., with its antenna aimed at the Earth.

b. The Balloons

Seven fixed instrument packages located at Bretigny, Kourou, Lago-Fagnano, Nouméa, Tahiti, Pretoria and Ouagadougou were interrogated first by the satellite. The purpose of this operation was to check out the satellite-balloon liaison system.

Balloon launching began on 21 August 1971 from the three stations at Mendoza, Neuquen and Lago-Fagnano, located in southern Argentina, and continued until 29 November.

*Numbers in the margin indicate pagination in the foreign text.

On 11 September a remote control error caused the destruction of two separate groups of balloons, the first near Africa and the second in the Australian zone. The figure of 72 balloons announced after this accident represented a total approximation. Title

Actually it was found later that the satellite could contact balloons situated beyond its visibility zone, which raised to 89 the total number of balloons receiving the destruction order.

The stations ceased their activity in sequence, depending upon meteorological conditions: /2

Mendoza, 8 October,

Neuquen, 9 November,

Lago-Fagnano, 10 December. Cover Page Source

At the flight altitude of the balloons the air masses which circulate are actually in a temperate or tropical regime. Quite often the latter case gives rise to very frequent icing and turbulence from November to March, phenomena which considerably reduce the service life of the balloons. (4th)

Thus, in the case of EOLE, the influence of the launching latitude could be checked statistically. The first results show that during the first month of flight balloon losses were established at:

Lago-Fagnano (55° S), 5%

Neuquen (39° S), 10%

Mendoza (33° S), 25%, this latitude being more subject to tropical disturbances.

c. Technical and Statistical Results of Balloon Launchings

a. Situation on 8 February 1972.

On 8 February 1972 the situation was as follows:

Total number of balloons launched:	479
Dead balloons	312
Active balloons	130
Doubtful balloons	37

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The doubtful balloons are those from which no more information is being received, but there is an obligatory waiting period of one month before declaring them out of service.

According to the evaluations of January and February, the mean loss is from 1.2 to 1.3 balloons per day. This allows a prediction of about 50 balloons active by mid-May.

b. Station Activity

From 21 August to 10 December 1971 476 balloons were launched by the group of three Argentine stations, representing an average of five balloons per day.

Mendoza: This station was opened for forty-nine days (21 August to 8 October). During this period the station had to interrupt launchings on twenty-one days for meteorological reasons. /3

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The Mendoza station launched a total of 100 balloons, or an average of two balloons per day.

(4th)

Neuquen: Opened for eighty-one days (21 August to 9 November), the station was inactive for a period of twenty-seven days. Neuquen carried out 202 balloon launchings, representing an average of two balloons per day.

Lago-Fagnano: From 21 August to 10 December the station was operational for a period of 102 days. Since the meteorological conditions were more unfavorable, the station was closed for sixty days. Lago-Fagnano launched a total of 174 balloons or an average of 1.7 balloons per day.

c. Balloon Seeding

The period included between 6 November and 2 December is the one in which the greatest number of active balloons were recorded, an average of 250.

The maximum was reached on 13 November with 280 balloons in flight.

Despite the accident of 11 September, the success of the experiment was assured since it was necessary to reach a number of 250 balloons in flight at the same time.

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The record balloon launching for the three stations was achieved on 27 August and 31 October with thirteen balloons launched.

The Mendoza station carried out eight balloon launchings on 20 September. This figure represents the maximum launchings carried out by one station in a single day.

d. Service Life of the Balloons

The mean service life of the balloons in flight is three months.

Two balloons launched on 26 August from the Neuquen station were still active on 1 February, representing 164 days of operation.

e. Death of the Balloons /4

Of the known causes of balloon disappearance the most frequent is the phenomenon of icing. However, nearly half of the balloons disappeared without the actual cause being determinable. There were very few cases of power breakdown.

f. Satellite-Balloon Liaison

For five months localization operated with no degradation of measurement quality. The system allowed the interrogation and localization of up to 300 balloons per day, each balloon being contacted two or three times per orbit, and this included up to seven orbits in a row at high altitudes (50° - 60° S).

Each day more than 2,000 interrogations were broadcast by the satellite and the results were put into a bank containing between 200,000 and 300,000 measurement points.

II. Data Processing

The Operations and Mathematics Divisions of the Space Center of Bretigny handled the entire processing of telemetry measurements coming from the network stations and the programming of the EOLE satellite.

These operations, carried out twenty-four hours a day, are summarized in the form of a flow sheet and attached hereto.

STATION ACTIVITY

	Days of Operation		Number of balloons launched
	Open	Closed	
Mendoza 21 August/8 October	49	21	100
Neuquen 21 August/3 November	81	27	202
Lago-Fagnano 21 August/10 December	102	60	174
Total	232	108	476 + 3 pre-series

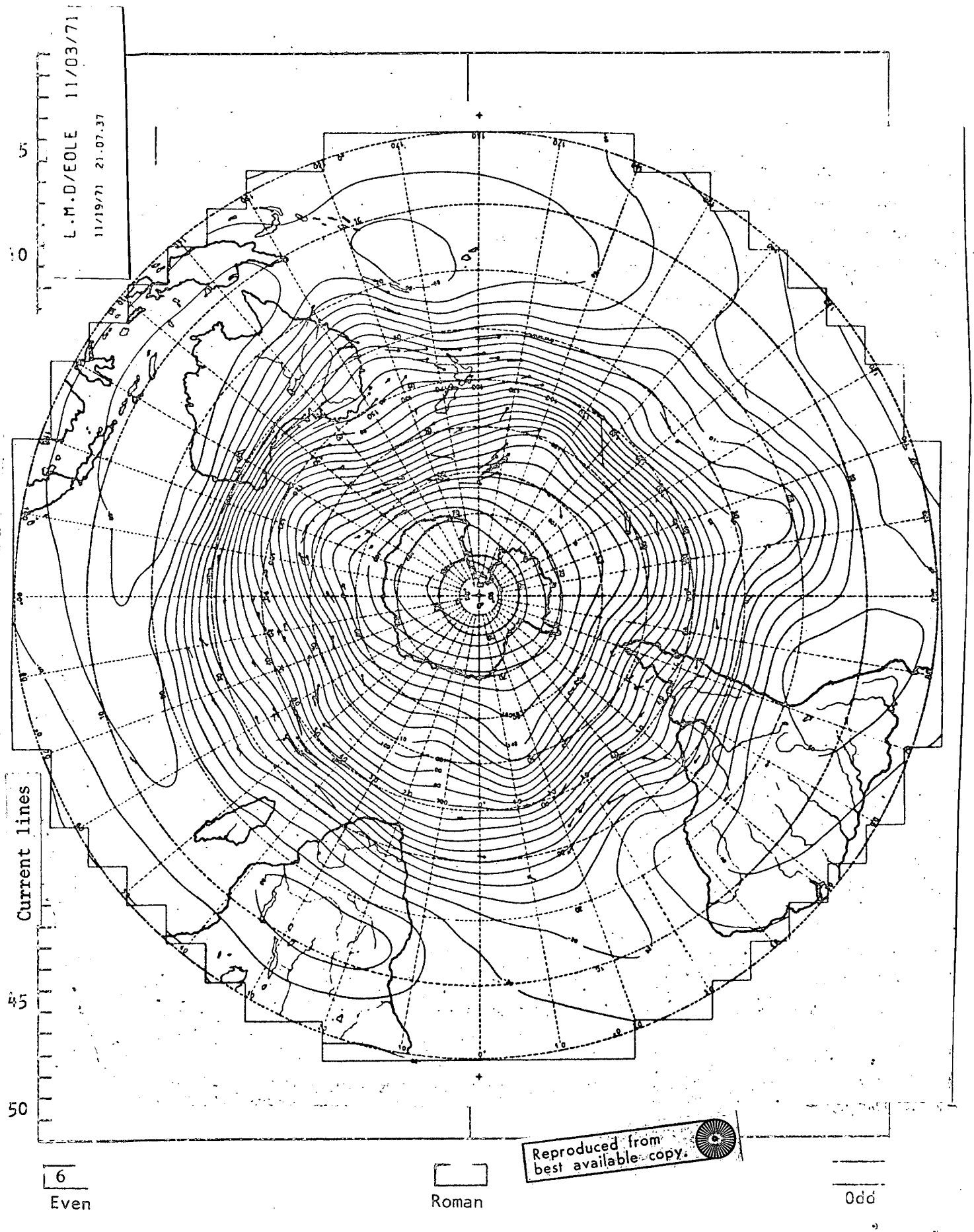
a. Data Acquisition

The crude telemetry data obtained at the station level are transmitted by telegraph line to the Bretigny Space Center. The flow of information arriving in a random fashion passes through a Thomson reception device (UBM) and is conducted by an acquisition and sorting program (A01) to the storage disk of one or two CDC 1700 computers connected in parallel and rapidly interchangeable in case of breakdown.

b. Processing of Telemetry Data

All processing is carried out by the CDC 6600 computer linked by the command of an operator to the output of the CDC 1700. The CDC 6600 guarantees the chaining of five programs (R.05, R.02, R.13, R.16 and R.11). The data are subject to a quality control R.03 which leads to data storage or to a request for message repetition.

The information accepted as usable is synchronized and separated (R.02). Two files are then set up for scientific telemetry (19) and for service telemetry (13).


L.M.D/EOLE 11/03/71
11/19/71 21.07.37
Current lines
Reproduced from best available copy.
6
Even
Roman
Odd

The data of file 19 are decommutated (R.13), while those of file 13 seed the R.11 program for the purpose of technical control of the satellite functions.

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The decommutation leads to the formation of two catalogs: one (file 11) containing all the buoys interrogated during the orbit under consideration, and the other (file 12) containing only the fixed compartments.

In addition a third file (2) is set up. This one accumulates the total of all observations carried out from the beginning of the experiment.

File 11 feeds the R.16 program which allows the localization of the buoys. /7 This program R.16 is also fed by file 15: summary of orbit parameters.

On the basis of:

the time of interrogation,

the distance and relative balloon-satellite velocity, and

the orbital parameters,

it determines the position of the buoy by longitude and latitude at the time the satellite passes within the view of the buoy. (4) It also furnishes the precision of the measurement.

With the help of the R.16 program, four new files can be established: files 14, 22, 1 and 3, the contents of which are provided in the appendix.

c. Programming of the Satellite

The second part of the processing stream is devoted to satellite programming.

It allows calculation of the moments of rendezvous of the satellite with the buoys beginning with their last known position from the satellite orbit assuming as a first step that the balloons and the buoys are fixed.

This second step in the stream includes only three basic programs which are engaged manually (R.14, R.15, R.17). The R.14 program calculates the rendezvous of the satellite for all of the buoys known, from the network stations and from the orbits described in twenty-four hours. These rendezvous are stored in file 16.

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With the help of this latter file, the R.15 program makes a selection among the possible rendezvous presented in the shape of a clearly written listing.

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This listing is translated into satellite language in file 17. File 17 can be the object of a control making additions and modifications. The incorporation of these modifications into the R.17 program makes up the definitive data of the teleprogram.

The teleprogram consists of punching a tape with contents to be sent to the telecontrol and telemeasurement stations and set into operation with an acknowledgement of receipt; this provides an opportunity to guarantee correct transmission.

d. Out-of-Stream Programs Cover Page Source

The out-of-stream programs are of several types:

-Programs connected with surveillance, security and restoration of files. These include the LIDIR program connected with guide file 9. It assures control of all the files.

(41)

-The calculation program of the orbital parameters.

-These parameters are calculated from the interferometric measurements made by the network stations. They are reviewed daily to guarantee the exactitude of localizations.

-Programs connected with the scientific pre-analysis of the data.

One of these programs is represented in the flow sheet: CORRIG, a program conceived and put into operation by LMD, examines the balloon trajectories and removes any doubt between two ambiguous positions obtained by the R.16 program and inherent in the method used.

-Programs for operating a fleet of balloons.

This refers to the NOUBAL and DETBAL programs shown in the flow sheet, which can be integrated into the stream to add or suppress entries relative to these balloons in files 10, 18 and 14.

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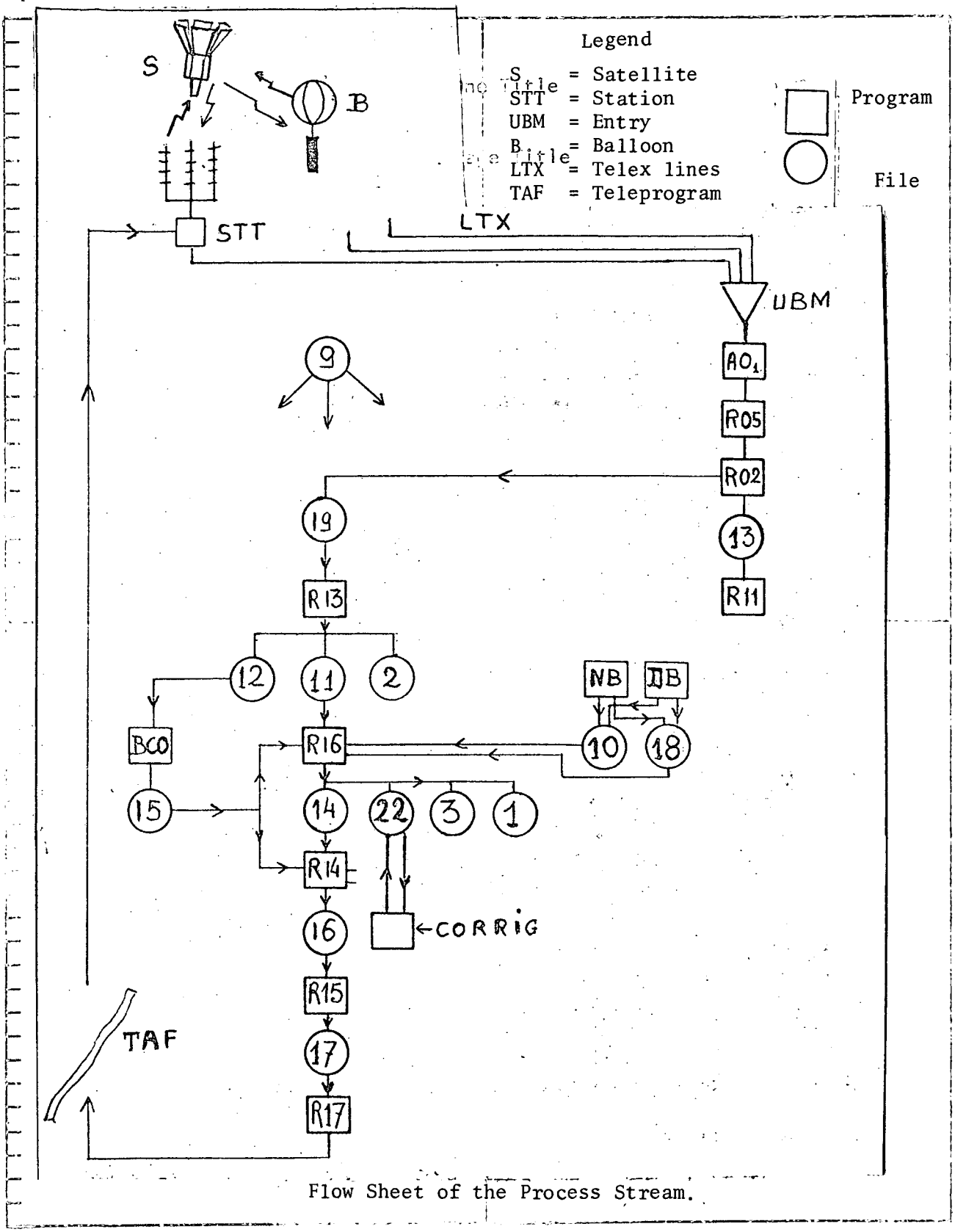

Flow Sheet of the Process Stream.

Visualization of the fleet of balloons on a screen or photograph, microfilms which can be stored, has been made possible by the VU 2000 and Calcomp programs.

Finally, a telex program produces a punched tape of the daily condition of the fleet of balloons, transferable to the various interested parties, and a final program allows the previous information to be edited at the central site or at a terminal.

List of the Programs of the "Telemeasurement Processing" and "Programming" Systems of the Satellite

R.05	Diagnosis of data quality
R.02	Synchronization of telemeasurements and separation of scientific telemeasurements and use telemeasurements
R.11	Technological control (operation of satellite and associated buoys)
R.13	Decommutation of scientific telemeasurements
R.16	Localization of balloons, fixed compartments, buoys....
R.14	Anticipation of satellite-buoy and satellite-station rendezvous
R.15	Selection and conversion of data into satellite language
R.17	Proposition of teleprogram.

List of the "Out-of-Stream" Programs Capable of Being Introduced into the Stream Above

NB	"NOUBAL" program providing the situation of new balloons during their launching
DT	"DETBAL" program establishing the list of balloons destroyed or disappeared.
CORRIG	Program to confirm removal of doubt between two ambiguous solutions.

List of Files

9	Guide file. Can interrogate or check at any moment all of the stream and out-of-stream files
19	"Scientific telemeasurements" file
13	"Use Telemeasurement" file
11	Catalog of buoys interrogated
12	Catalog of fixed compartments

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2	Accumulation of observations from the beginning of the experiment
10 & 18	Inventory of the balloons in service and of the balloons destroyed or disappeared
15	Summary of orbital parameters
14	Last known position of each buoy
22	Accumulation of successive localizations of balloons and of associated parameters
3	Accumulation in a condensed form of the position of all objects
1	Accumulation of the successive positions of the buoys associated with the experiments.
16	Establishment of the possible satellite-buoy and satellite-station rendezvous
17	Summary of data converted into satellite language forming the rendezvous program for the next orbit. These data constitute the content of the message on the teleprogram tape.

III. Preliminary Results of the EOLE Experiment by P. Morel[1]

Really detailed scientific exploitation of the observations made during the EOLE experiment was able to begin after a relatively prolonged elaboration period which allowed errors in geographical localization to be reduced and the limit of accuracy of this system of navigation to be set at about 2 km, even for balloons in rapid movement around the Earth. This exactitude corresponds to an uncertainty of 0.5 m/sec for the mean wind determined for the time period between two successive passes of the satellite.

In conformity with the objective we had set for ourselves, the balloon launching program from the three stations of Mendoza, Neuquen and Lago Fagnano permitted an almost homogeneous distribution of balloons to be put in place from November 1971 on in all the Southern Hemisphere latitudes, naturally excluding the tropical latitudes. After the end of the launchings, the number of balloons present in the vicinity of the tropics progressively diminished so that the major portion of the remaining vehicles is now found at latitudes higher than 45°. This fact in itself constitutes the first scientific information informing us of the rate of mixture of the "polar" air consituting the

[1] Professor at the University of Paris VI, Associate Director of the Laboratory of Dynamic Meteorology of the C.N.R.S. (National Center for Scientific Research).

general western circulation with the "tropical" air, more or less stagnant or driven by the eastern trade winds.

The total population of active balloons, reaching 280 at the beginning of November 1971, is decreasing at the present time according to the exponential law characteristic of a random duration of individual flights. The rate of reduction found, 50% every two months, corresponds to a mean duration of active flights (electronic systems working) of three months. In addition it seems that half the disappearances can be attributed to a distinctive tive atmospheric phenomenon. It is found that these distinctive phenomena are almost exclusively located in the tropical zone, more precisely in the three regions associated respectively with the basin of the Amazon, equatorial Africa and finally in an almost permanent stagnation zone situated between Australia and the American continent. The existence of this quasi-stationary perturbation of the tropical air front was not known before the EOLE experiment and will be the object of a special climatological study.

The number of balloons in flight became large enough from October on to (4") /13
set up daily a hemispheric map of the general circulation of the atmosphere at an altitude level of 200 mbars. These maps are represented essentially as a series of sinuous lines, current lines, indicating the direction of flow and showing the limits of deviations. These hemispheric maps allow the evolution and progress of these deviations (perturbations) of the flow around the Earth to be followed from day to day, information obviously of great practical interest in predicting the arrival of these perturbations at a particular point in the Southern Hemisphere. This information also presents a great deal of scientific interest because of the relative simplicity of the topography of the Southern Hemisphere which makes it possible to compare atmospheric circulation with simple mathematical models. Finally, these daily maps of current lines allow the spectral distribution of the kinetic energy of the wind to be evaluated very precisely between the mean zone circulation and the perturbations of different wavelengths.

At the same time, prolonged study of several hundred tracers following the horizontal flow of air masses allows the direct measurement, with a precision

unknown in the past, of the mean meridional movement (north-south) of the atmosphere and the divergence (or convergence) of the flow. These precise measurements for the first time allow quantitative study of the divergence associated with perturbations of various gradations, since on the average the smaller the gradation envisaged, the larger the values measured. It has especially been shown that the instantaneous and local values of horizontal divergence reach ten times the mean value found for a two-week period at the same latitude. This very poor mean divergence of flow is compatible with the extremely weak mean meridional velocities, on the order of 10 km/day, which are established by us by following the balloons for about ten days. It is not surprising that such a weak mean meridional circulation has always previously been masked by the large deviations of momentary circulation. Obviously a much larger meridional velocity is found in the tropics, at least 100 km/day, characteristic of the classical circulation of Hadley's cell.

Finally, the study of the random dispersion of tracers launched at the same time from one station or the very accidental meeting of them during pre-flight has allowed the exponential law characteristic of diffusion in a horizontal isotropic turbulent flow (in two dimensions only) to be verified. This allows us to specify the rate of mixture of a particular mass of air with the rest of the fluid which takes place just as much in the diffusion of a radioactive cloud, e.g., as in the real dynamics of the atmospheric circulation causing a sort of viscosity which dissipates the kinetic energy of the perturbations. /14

These very incomplete preliminary results obtained at the present time by the Laboratory of Dynamic Meteorology of the C.N.R.S. are far from forming the entirety of the scientific harvest we expect from the EOLE experiments. We should indeed remember that several teams of the scientific community, in particular in the United States, are participating with us in analyzing the EOLE data and will certainly find the germ of new ideas, the future impact of which cannot be stated clearly.

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IV. The Complementary EOLE

/15

Localization and data collection correspond to an extensive gamut of needs: message transmission, oceanography, hydrography, meteorology, geophysics, cartography, topography... However, the novelty of the service offered and the great scattering of the demand make it indispensable to carry out exploratory experiments for the orientation and conclusion of future programs, motivated by two kinds of preoccupations:

--one of a promotional order, in order to demonstrate to potential users the possibilities and performance offered by the space systems in localization and in data collection;

--the other of a technical order, to face all the problems raised by the installation of such a system: the importance of jamming, problems in satellite programming, rapid processing of data. On the basis of these tests it will be possible to orient future systems conceived by CNES according to need.

a. The Complementary Experiments

Review of the needs formulated by users has led to the definition of several sorts of experiments. Among these experiments we will distinguish:

--localization experiments,

--localization experiments with message transmission,

--localization and data collection experiments on the basis of drifting buoys,

--localization and data collection experiments with Earth responders.

1. Localization Experiments

EOLE can be used to find the location of objects moving at a low velocity on the globe. For different reasons people have therefore considered following an iceberg and localizing a research ship.

/16

The French Polar Expeditions will use a helicopter to place a responder on an iceberg coming from Terre Adélie toward the beginning of March 1972. An iceberg floating northward will be chosen to prevent its early reincorporation into the ice pack, and after its reincorporation the ice flow which shifts to quite a degree will be followed.

The "Gallieni", chartered from 9 February to 8 March 1972 by the French Austral and Antarctic Lands (T.A.A.F.) and from 9 April to 15 May 1972 by the Institute of Global Physics, will carry out oceanographic research campaigns in the Indian Ocean. For these experiments precise and frequent localization of the ship is indispensable.

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For this reason the idea was broached of using an EOLE responder to make up for the problems posed by localization in this region of the globe. The heading and speed of the boat will be collected at the same time, and this will allow localization exactitude to be improved.

2. Localization Experiments with Message Transmission

In these experiments it is convenient to distinguish two areas of application:

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--commercial applications;

--scientific applications.

The commercial applications include centralized operation of a fleet. This is a matter of evaluating the importance of centralized operation of a commercial fleet with the help of message transmission providing information about the activities and simultaneous localization of ships.

(4")

By means of this data a very complete record of these fleets can be maintained and followed right after each rotation period.

This experiment undertaken with the assistance of the Merchant Marine, of the Post Office and Telecommunications Department and the Committee of Ship Builders, will be carried out with three ships of the Chargeurs Reunis Maritime Company: "Dupleix," "Forbin," and "Ango."

A responder analogous to the one used on the balloons will be placed on each ship.

The experiment will begin next May after the operation procedures are tested and the new processing programs verified.

The purpose intended by the users is to prove that operating messages, ordinarily sent by radio, can be transmitted directly by satellites. /17

Exploitation of the results will consist of removing difficulties met, establishing percentages of poor transmissions, and evaluation of delays in restoring messages.

At the same time indications of the condition of the sea, the wind and the movements of the boat will be noted on board and permit correlation of the difficulties met and the environmental conditions during the broadcast.

Scientific Applications

a. Oceanographic Research

The Scientific and Technical Institute of Maritime Fishing (I.S.T.P.M.) is carrying out oceanographic and biological research campaigns for which it needs precise localization (making of fish maps) and data transmission.

A primary experience was carried out from 7 January 1972 to 5 February 1972 in the Gulf of Gascogne with the I.S.T.P.M. ship "Thalassa." The messages transmitted concerned the results of the day's research (nature and quantity of fish taken, number of trawling runs).

The I.S.T.P.M. has stated that it is completely satisfied with the localization and is looking forward to continuing these experiments from March to June 1972 to the extent that the equipment can be kept on the ship until that time.

b. Petroleum Prospecting

Petroleum prospecting companies are carrying out research campaigns at sea by means of ships carrying a large amount of seismic equipment.

Petroleum prospecting is based on two requirements capable of being satisfied by spatial means:

very precise and continuous localization,

transmission of a very large amount of data.

It is obvious that EOLE is not in a position to satisfy either of these requirements immediately.

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However, the General Geophysical Company (C.G.G.) interested in the services rendered by the satellites, is looking forward to an experiment to begin in April 1972.

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The purpose of this experiment, using one or two ships, is to assure the consistency of research operations thanks to transmission of messages concerning the daily evolution of the campaign.

In addition it will be possible to make a comparative study of the exactitude of localization furnished by EOLE with current means of navigation available to the ships (Transit system).

c. Meteorological Messages

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The delay established by the World Meteorological Watch for transmission of messages originating on meteorological ships is two hours, 30 minutes between the moment of observation and that of diffusion in the exploiting centers. In fact this margin is grossly exceeded (4") and average delays of five to six hours are frequently met with.

A number of reasons clarify these delays:

First of all, the messages are broadcast by the on-board radios. Now, since these do not guarantee night service, findings from this period are transmitted with a delay capable of reaching twelve hours.

In addition, vacation hours of coastal stations or their congestion contribute to delaying transmissions. Finally, certain countries lose a high percentage of the messages.

It takes about forty-one minutes in France to receive messages at the Central Meteorological Center (before rebroadcasting to other centers), but 128 minutes for the N.O.A.A. center in the United States of America or in Melbourne, 198 minutes for Rome and 212 minutes for Karachi.

Thus the space systems are capable of bringing very definite improvement in message transmission. Their automatic functioning makes them a very handy

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tool, independent of any one's schedules and of the position of the ship. These, then, are the possibilities of the system which will be experimented with by three ships of the General Transatlantic Company: the "France," the "Auvergne," and the "Anjou." The experiment will begin at the beginning of March 1972.

Some statistics on meteorological message transfer time from the moment of observation to insertion into the meteorological circuit:

3. Localization Experiments and Data Collection From Drifting Buoys

The use of drifting buoys for information collection and for localization is an original process under experimentation for the first time with the EOLE satellite. This experimental principle is a response to various needs.

Laboratory of Dynamic Meteorology

For Professor Morel, Scientific Director of EOLE and Associate Director of the L.M.D., the launching of EOLE constitutes a chance to study the ocean-atmosphere interaction. For this purpose the L.M.D., in collaboration with the University of British Columbia, has proposed observation of the details of a large ocean current and characterization of its fluctuations on a small time and space scale.

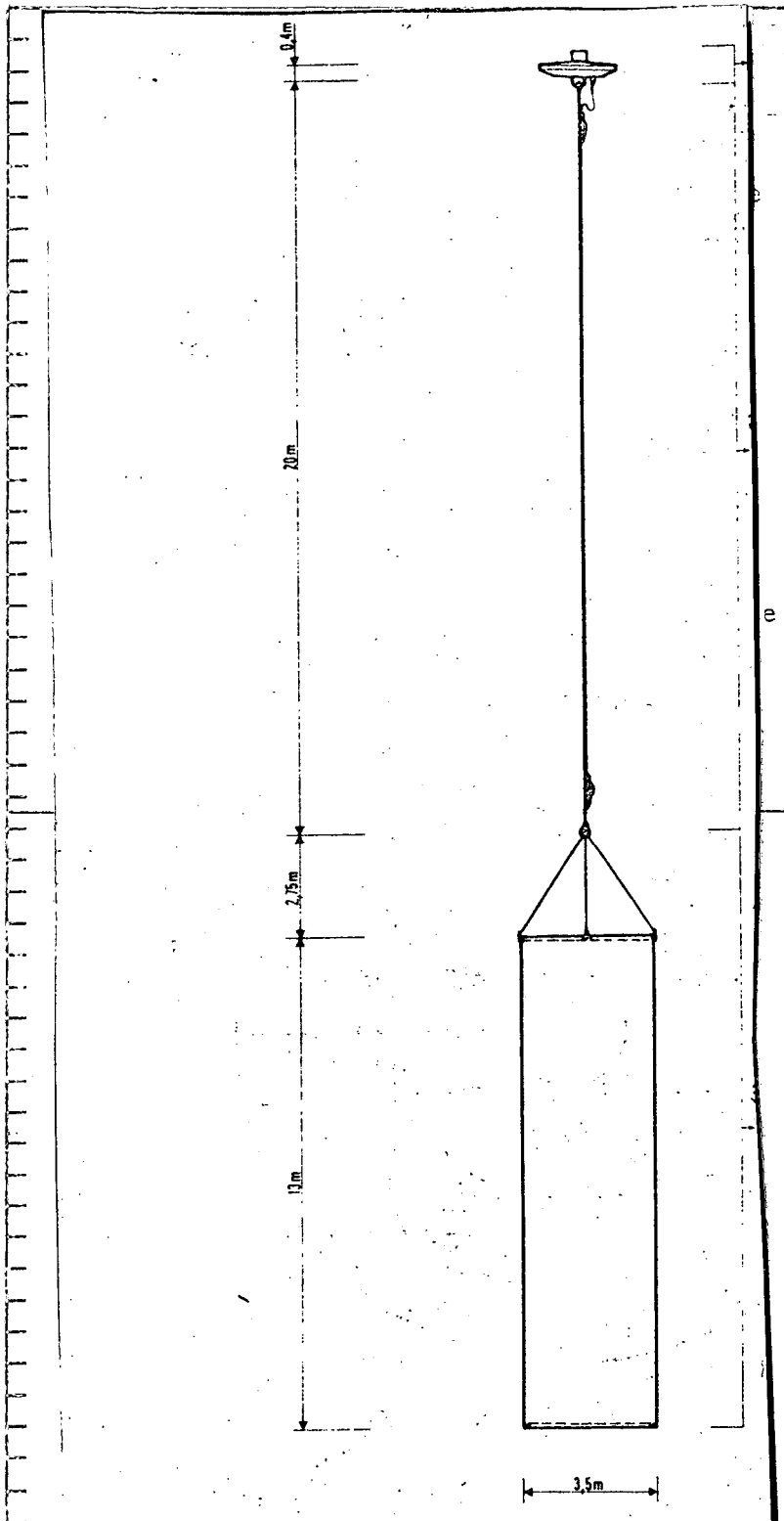
Ten drifting buoys in the shape of a disk 2.10 m in diameter and 0.45 m in thickness, made of fiberglass, serve as current tracers by using a sail 45.2 m^2 submerged 30 m deep.

The buoys, equipped with EOLE responders identical to those used in the balloons, take several measurements:

Scientific measurements: temperature of water at surface,
temperature difference between surface and twenty meter depth,

Technological measurements: temperature in the buoy,
battery voltage.

Ten buoys were set adrift on 2 February off Vancouver in two groups of five, two to three nautical miles apart. The projected experiment consisted of following the mean shift between the groups and the relative distances between the buoys of one group.



Subassemblies: buoy and compartments

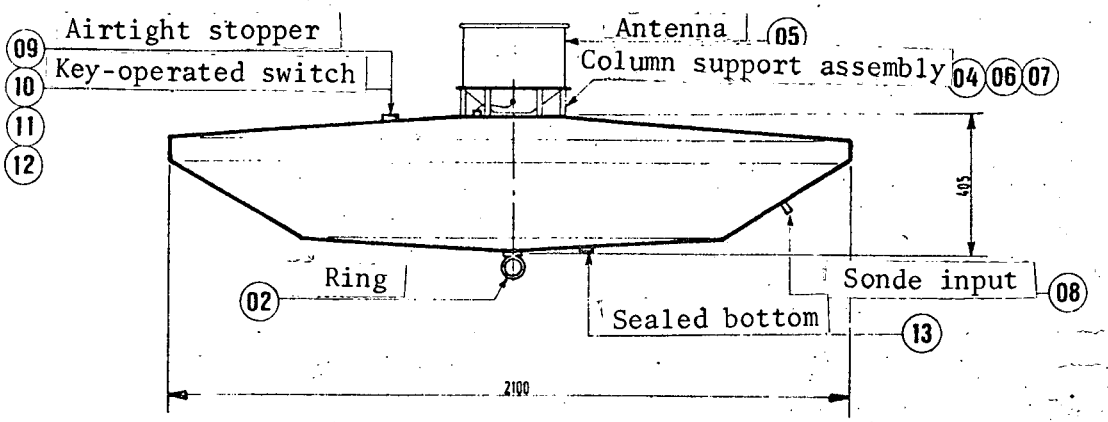
Automatic cable carrier subassembly

(4'')

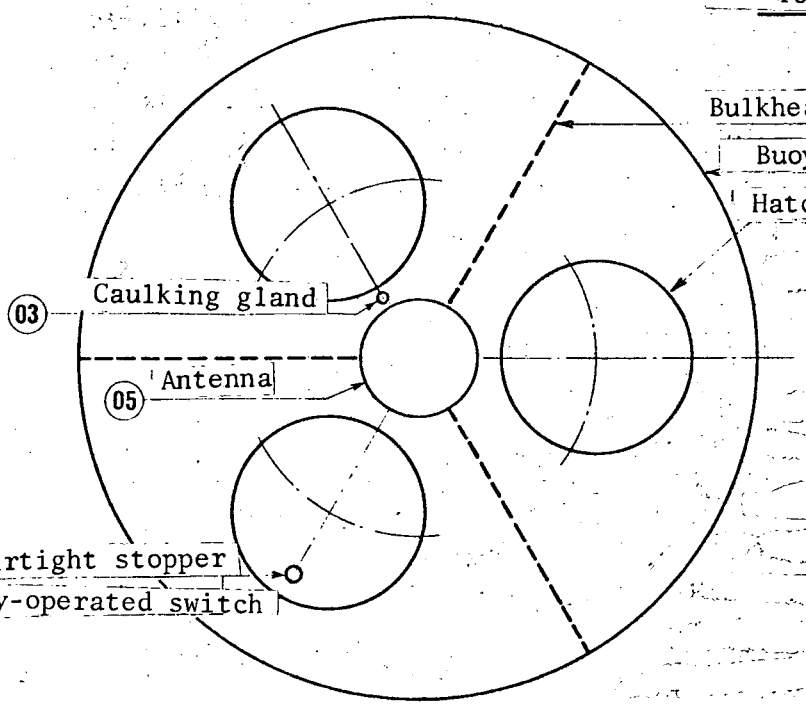
Sail and sling sub-assembly

Drifting Buoy Assembly

06



Top view



Buoy subassembly

07

French Austral and Antartic Lands

The T.A.A.F. Administration, which conducts oceanographic research in the Indian Ocean, wishes to use eight buoys similar to those developed by the L.M.D. to study the sub-Antarctic convergence along the Kerguelen Plateau, where the water dynamics are not well known: the buoys will be set adrift around 20 March 1972 and their successive trajectories will be followed.

National Center for Ocean Exploitation (CNEXO)

The CNEXO has had a light drifting buoy developed for the purpose of serving as a collection station for oceanographic or meteorological data.

This type of buoy offers several advantages: simple to put into operation, resistant to shock, great stability.

Their low mean velocity and their service life, greater than those of anchored buoys, allow consideration of their use in forming the basic elements of permanent operational networks.

The maintenance cost of such a network is then tangibly less than that of a network of anchored buoys.

A double experiment will be carried out with EOLE:

a drifting buoy, which an attempt will be made to recover, will be set adrift in the Gulf of Gascogne in March or April 1972,

a buoy anchored in the Brest Roadstead will serve as a technical evaluation buoy.

National Oceanic and Atmospheric Administration

The N.O.A.A. wishes to carry out an oceanographic experiment by following five or six drifting buoys which will be put into the Gulf Stream. This experiment has not yet been completely defined.

Ministry of Agriculture, Fisheries and Food of the United Kingdom

The Fisheries Laboratory of Lowestoft is carrying out research on the fishing resources of the North Sea and of the Atlantic.

Two separate experiments, based on the use of buoys supplied with a very deeply submerged sail system (1,000 meters) will allow corresponding masses of water to be followed.

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The first experiment was to begin at the end of April 1972 in the North Sea with one buoy.

The second experiment would put two buoys into operation in the Gulf Stream at the beginning of May 1971. /21

Australian Meteorology

Australian meteorologists and oceanographers are also looking forward to setting up operational networks of light drifting buoys collecting oceanographic and meteorological data.

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A responder would first be tested on the ground, then on a boat, before being placed on a drifting buoy. This experiment has not yet been purposely defined.

4. Experiments in Data Collection by Ground Responders

There still remains an era of privileged application of space resources: that of collecting and centralizing hydrological, climatological and meteorological data.

Such a system is of particular interest to countries where the internal telecommunication network is insufficient or whenever complete automation of data collection and processing over a large geographic tract is indispensable for insertion into forecasting models.

Several countries have shown their interest in the Complementary EOLE program.

Argentina will put into operation three responders collecting measurements of precipitation, snow depth and flow of water courses. The responders will also be able to take meteorological parameters (temperature, pressure, humidity, wind);

Brazil will use four responders for similar experiments;

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India will put into operation four responders to collect meteorological data;

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Italy will carry out two experiments: one with two responders for transmitting meteorological data (temperature, pressure, humidity, wind) and a second, also with two responders, to collect meteorological and oceanographic data for scientific purposes (the establishment of oceanographic and meteorological forecasting models in the Adriatic).

Within the framework of Complementary EOLE experiments, CNES has proposed /22 to explore the principal areas of application of the space systems for localizing and collecting data.

The possible users have given a very wide response to the offers of CNES to go on with tentative experiments; 17 experimenters will put into operation 57 responders for 19 different experiments.

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B. Needs for Localization and Data Collection: Economic Expectations /23

At the demand of CNES, the Bureau of Economic Information and Forecasts (B.I.P.E.) has made a study of the market for needs of localization, collecting and distributing data. (4")

Out of about 100 organizations queried, about fifty have responded favorably to the questions put to them.

General Remarks

The inquiry refers to French needs for the years 1971-1975-1980. Thanks to the information given by the users, it has been possible to make an estimate of needs on the world level.

The costs expressed include the investments which the users would be ready to devote to the satellite systems and their operating expenses.

For localization the unit is the buoy point or month, i.e., one month of activity of one buoy. This unit was chosen in order to be able to treat all users disposed to rent or buy buoys in the same way.

In the latter case, we count twelve buoy months per year and per buoy bought.

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The unit for data collection is the buoy.

The totality of needs expressed represents the potential market for localization into data collection. Still, since this volume of needs does not correspond to the real market of a satellite system, they are proceeding at the present time with an economic study to determine the performance-cost ratio and concurrent systems.

1. Needs for Localization in Order of Decreasing Precision: World Estimate: 1980. /24

TABLE 1.

Precision: 1 m to 10 m (fixed point)

Disciplines	Number of points/yr		Market value (MF)
Petroleum	1,500 × 4 = 6,000		32.25
Geodesy	480 × 20 = 9,600	(4')	35.70
Topography	6,500 × 30 = 195,000		340.00
Cartography	240 × 30 7,200		36.00
Glaciology	20 × 4 = 80		0.40
Total 1980	8,7000 24 = 216,000 points		444 MF
Average net cost per point	2,000 F/point		

Each discipline includes several activities and each activity includes several users.

The second column represents the number of localization points requested by the French organizations and societies multiplied by a coefficient for extrapolating from the national market to the world market.

The third column is the value of the world market corresponding to the volume of the world demand expressed in the second column.

TABLE 2. PRECISION: 50 m (MOVABLE POINTS)

Activities	Number of Buoys/Months	Market Vallue
Petroleum	1,570	18.50 MF
Hydrography	12 × 100 = 1,200	45.00 MF
Oceanography	50 × 27 = 1,350	44.30 MF
Total 1,980	176 17.5 = 3,120 months/buoy/year	107.80 MF

Mean net cost of a buoy month 36,000 F

This type of need includes the request for localization of research ships: oceanography, hydrography and seismic prospecting ships at sea (detailed studies). For these various sectors the precision desired is continuous by 50 m or about 10 m every half-hour or three-quarters of an hour with a means of reckoning.

(4'')

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TABLE 3. PRECISION: 100 m to 1,000 m

Activities	Number of buoy months/year	Market value
Petroleum	C58ex Page=T232	11.6 MF
Fishing: search vessels	15 × 10 = 150	1 MF
Cable layers	15 × 20 = 300	10 MF
Polar expeditions (expedition vehicles)	2 × 10 = 20	0.8 MF
Coastal navigation:		
Fishing	280 × 25 - 7,200	30 MF
Commerce	700 × 25 = 17,200	71.65 MF
Oil vessels	70 × 25 = 1,720	7.16 MF
Total 1,980	Cover Page Source 26,800 mn	132 MF

Mean net price of a buoy month: 5,000 F/buoy month.

Most of this market corresponds essentially to the request for fishing and commercial ships and for oil vessels for coastal navigation. Localization needs for seismic prospecting at sea appear to be of secondary importance (wide reconnaissance study). (4")

The first category of need is actually the most random in view of the importance of concurrent systems. Since the latter are not entirely satisfactory at present, they can be improved on the one hand by 1980 and on the other may remain at a very low use cost.

However, we have made a very pessimistic estimate of needs by considering only the most automated ships of the fleet (50 ships of the commerical fleet in 1971 or 600 buoy months with a growth rate of 2% or 700 buoy months in 1980.

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TABLE 4. TOTAL MARKET 1980.

Precision	National Market		World Market		% Nat. mkt. World mkt.
	Quantity	Price	Quantity	Price	
1 to 10 m	9,000 points	22 MF	216,000 p	444 MF	5%
50 m	176 buoy/months	6 MF	3,120 buoy/mos.	108 MF	5.5%
100 to 1,000 m	1,150 buoy/months	8 MF	26,800 buoy/mos.	132 MF	6.25%
Grand Total	9,000 points 1,316 buoy-months	36 MF	216,000 p 30,000 buoy/mos.	684 mF	5.25%

2. Need for Collecting and Transmitting Data /28

The needs are divided into three areas: scientific, technical and commercial. (4")

This classification emphasizes the different uses of a localization and data collection system.

In the first table where collections of messages of low volume are estimated (with the exception of swell measurement), the needs correspond to the possibilities provided by a system of successive satellites.

In this regard it should be noted that the number of stations which could carry out data collection at the present time are still manual. Their automation can be anticipated after a period which will be a function of technical progress and of financial resources available.

The needs shown in the second table seem to refer more to the geostationary satellite area.

These forecasts give a general idea of the market for 1980. But they must be considered with prudence, since the present systems technologically limit the categories of use for data collection.

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Therefore it is difficult to verify precisely the future volume of the demand which will definitely depend upon the adequacy of the technological resources.

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ESTIMATE OF WORLD NEEDS IN 1980

1. Hydrological, oceanographic and meteorological data collection

	Number of buoys in service	Annual world market value (MF)
Hydrology:	10 to 30 bits/message, 1 message about 6 times a day	
	40,000	44
Oceanography: low volume	150 to 400 bits/message 2 to 4 times per day	
	300	45
Large volume of information:	$6 \cdot 10^5$ (swell measurement) (4) times per day	
	300	15
Meteorology:	250 to 4,000 bits/message 4 times/day	
	5,000	12.5
Climatology:	50 to 250 bits/message	
	4,000	10
Total:	49,600 buoys →	126.5 MF

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2. TRANSMISSION OF DATA ALONE

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Daily volume of information (bits)	Number of buoys in service	Annual market volume (MF)
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	Seismic prospecting at sea	
$5 \cdot 10^9$	35	7
	Seismic prospecting on land	
$2 \cdot 10^7$	200	25
	Various (seismology)	
$4 \cdot 10^4$ to 10^9	20 to 30	3 to 4.5
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	Total: 35 to 36.5 MF	

In line with these forecasts the markets for localization and for data collection appear under two aspects:

--the market for localization is organized around large users whose services are quite extensively commercialized and whose needs on the whole can be fairly well satisfied by existing systems;

--on the other hand, the market for data collection particularly concerns widespread users with objectives not aimed directly at commercialization. In most of these cases it is a matter of scientific organizations or those in the area of public interest. For this last category of users needs are still only partially satisfied.

A better definition of the objectives and technical resources to put into operation would lead to an increase in demand.

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